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POTATO SCAB AND SULFUR DISINFECTION



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POTATO SCAB AND SULFUR DISINFECTION

C. D. SHERBAKOFF

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THE SCAB DISEASE OF POTATOES

The disease of potato tubers known almost universally as scab is of very wide distribution. It occurs in practically all the potato-producing countries of the world and is particularly widely distributed in the United States. The severity of the attack varies in the different countries and in different sections, but is of sufficient importance in practically all countries to have elicited the attention of plant pathologists, many of whom have made some study of the disease particularly with reference to its control.

The disease is well characterized by the name given to it. The lesions vary from small, roughened spots to deep pits and irregular channels having a rough, corky lining. They may occur in isolated areas, or may be so extensive as to involve the entire surface of the tuber.

The apparent difference between the deep and the shallow scabs appears to lie chiefly in the extent of injury and is evidently due to the conditions of development of the lesion. A condition generally spoken of as wormy scab is frequently observed. It appears to the writer that Professor Thaxter's contention is yet the one most acceptable. Thaxter (1891:83) states that it is of common occurrence, especially in "deep" scab, that a variety of insects, especially wireworms, myriapods, and mites—for which the scab spots form an attractive feeding ground—often extend the injury, but are not the original cause of it.

Badly scabbed tubers are rendered unmarketable although the culinary qualities do not seem to be diminished materially. It is not apparent that the occurrence of the disease results in a decrease in number or quantity of tubers. In the case of seed stock the occurrence of a slight amount of scab on the tubers is sufficient to cause their rejection unless disinfection is practiced. From the nature of the disease it is obvious that there are no definite statistical data at hand in regard to losses; but, considering the importance of the potato crop and the very general occurrence of the disease, the losses from it are an important item.

Thaxter (1891) proved that this disease is caused by the activities of an organism which he named *Oospora scabies*. Thaxter only tentatively placed the organism in a class of the lower fungi. It appears to belong more properly to a group of the lower plants that occupy an intermediate position between true fungi and bacteria. More recently Cunningham

(1912) proposed to transfer the organism to the class of higher bacteria, to the genus *Streptothrix* Cohn. On this point Morse (1912) is in full agreement with Cunningham.

But according to Güssow (1914) this generic name cannot be used for this and related organisms, because it was earlier used by Corda for a hyphomycetous fungus. According to Güssow the potato-scab organism belongs more properly to the genus *Actinomyces* Harz, and he has named the scab organism *Actinomyces scabies* (Thaxter) Güssow.

This organism—although it is a true parasite on the potato and is commonly carried from crop to crop on the seed tubers—may, according to Jones and Edson (1901), live saprophytically in the soil for twenty-five years or more without intervention of the host plant.

When land is not contaminated with the scab organism, the new crops can be kept free from the disease only by planting seed tubers that are absolutely free from the parasite. Tubers that do not show scab lesions are commonly selected for seed, but, since the scab organism may be present on the surface of the potato either in a minute lesion or merely adhering from chance contamination, it is becoming common practice to treat all seed stock with some one of the standard disinfectants.

When the soil becomes contaminated with the scab germ, seed treatment is of no value unless some method can be devised for eradicating the germ in the soil. In many parts of New York State the disease is held to a satisfactory minimum by a long rotation and by a proper system of fertilization. For the potato specialist who wishes to grow potatoes on a limited area and in short rotation, this practice is not applicable. It is in order to meet such conditions that many attempts have been made to find suitable soil germicides.

A very large number of substances have been tested experimentally. One of these substances, to which germicidal value is usually attached and which has been tried in a number of experiments, is sulfur. It has been the object of the investigation herein reported to determine the value of sulfur in the control of potato scab on a definite potato soil type occurring in the State.

SULFUR TREATMENT OF SOIL FOR PREVENTION OF POTATO SCAB

Work done by other investigators

The first recorded experiment on sulfur treatment of the soil for prevention of potato scab is that of Taft (1890). In his experiment flowers of sulfur, 300 pounds per acre, was tested along with various other substances for the control of scab. The result reported shows neither beneficial nor harmful effects from the sulfur treatment.

Bolley (1891), in his experiment on the effect of various substances when used for treatment of seed tubers for the prevention of scab, found that rolling the seed tubers in flowers of sulfur resulted in a crop with 48.6 per cent of scabby tubers; hence he concluded that the treatment was worthless.

Coincident with Bolley, Thaxter (1892) also performed a small field experiment "to test the effect, if any, of sulfur and of muriate of potash used as a fertilizer in the hills, upon the amount of scab produced in tubers grown on land known to be infected." He found that there was no difference between treated and untreated hills, "the tubers being very generally scabbed in all cases." In his report the quantity of sulfur used is not given.

Goff (1893), in his experiment on the use of sulfur, employed two slightly different methods of treatment. In one case the seed tubers were dipped in water and then rolled in flowers of sulfur; in the other case the seed tubers were first dropped, and then, before covering them, half a teaspoonful of flowers of sulfur was sprinkled over each tuber and the soil about. In the experimental rows half the hills were treated, while the other half were left without treatment. The result of this experiment is as follows:

	Percentage of clean tubers
{ Seed tubers rolled in sulfur.....	77.7
{ Untreated.....	64.0
{ Sulfur sprinkled over seed tubers.....	57.5
{ Untreated.....	51.3

From the above data it is evident that there was very slight, if any, decrease of scab due to either of the treatments.

Pammel (1895) treated potato seed-tubers with corrosive sublimate and sulfur. The latter was employed in "solution," 1 pound of sulfur to 7 gallons of water, the treatment lasting for two hours, one and one half hour, and one hour. The 144 hills planted with seed treated with sulfur in the above manner had 51 per cent of scabby tubers, while the 48 untreated hills had 74 per cent of scabby tubers. In regard to the experiment as a whole, the author says: "The results are so discordant that no general conclusions can be drawn."

Halsted (1895), in his experiment performed in 1894 at Freehold, New Jersey, among other substances tried sulfur for soil treatment in connection with potato scab. Flowers of sulfur was used at the rate of 600, 300, and 150 pounds per acre, and one plat was planted with seed tubers rolled in sulfur. The apparently excellent result obtained from sulfur treatment is rendered worthless as a proof of the germicidal value of sulfur in the soil, because a mere rolling of seed tubers in sulfur, as well

as the treatments with corrosive sublimate and copper sulfate, gave equally good results.

Halsted's work on soil germicides, including sulfur, was continued for five years more, the method of sulfur treatment being varied from rolling the seed tubers in a given quantity of sulfur and then dusting the remaining sulfur over the seed tubers before they were covered, to mixing the sulfur with five times its bulk of dry soil and working the mixture into the soil with a fork. In no case was the quantity of sulfur used in a single application above 720 pounds per acre. Details of the methods employed and results obtained in these experiments can be found in Halsted's several reports (1897 a, 1897 b, 1898, 1899 a, 1900). The principal results obtained, so far as the data go, are:

1. In one out of many instances, an application of sulfur at the rate of 300 pounds per acre greatly reduced the amount of scab annually from the first year of the application to nearly the end of the experiments.

2. No reduction of scab was obtained by even the heaviest application of sulfur, 600 pounds per acre, in 1896, nor was the effect of the treatment noticeable in the following season.

3. The same treatment, which had no effect on scab in either the season when the application was made or the season following, was evidently fairly effective in the season of 1898, when the average amount of scab on the treated plats was 25.3 per cent while on the check it was 61.4 per cent.

4. The plats that received 720 pounds of sulfur showed, in 1898, the greatest and most uniform reduction of the scab—from 50.8 per cent on checks to an average of 12.5 per cent on the treated plats; but the crop on the treated plats was only a little more than half that on the untreated area (1899 a:306).

5. In 1899 a new application of sulfur at the rate of 300 pounds per acre did not show any reduction of the scab. Nor was there any noticeable reduction in any other plats treated during previous years except the three "belts" of plat 2, series 6, where the reduction of the badly scabbed tubers ranged from 59 per cent in checks to 22 per cent on the treated "belts."

From the above summary of the data presented in Halsted's reports, it is clear that his conclusion that "for practical use, 300 pounds applied to the open row are deemed sufficient" appears to have very little ground.

At the same time, it is also plain that when a sufficient quantity of sulfur is applied—in his case this quantity was about 720 pounds per acre—the scab can be reduced to a considerable extent not only during the season of application but also during the season following. When a large quantity of sulfur is applied, under certain conditions there may be also a great reduction of yield.

Brooks (1897) performed a small field experiment in order to determine the effect on potato scab of sulfur application in open furrows at the rate of 300 pounds per acre. Untreated seed and seed treated with a solution of corrosive sublimate were used. The treatment with sulfur appears to have been absolutely without any effect on the scab.

Chester (1897) reports results of an experiment in rolling seed tubers in sulfur for the prevention of scab. Tubers so treated yielded a crop of which 9.1 per cent were scabbed, as compared with 29.5 per cent of scabby tubers among those untreated.

Chester (1898) conducted another experiment on the use of sulfur for the prevention of scab. This time two field plats, seventeen by seventy feet, were used. One of the plats received an application of flowers of sulfur at the rate of 300 pounds per acre. The sulfur was spread broadcast and then harrowed in just before planting. The sulfured plat produced tubers with 12.4 per cent of scab, while the check gave 26.8 per cent of scab.

Garman (1898) performed two experiments on potato-seed treatment with sulfur flour and corrosive sublimate against scab. In one of these experiments six pots with sterile soil were used. The seed tuber for one pot was rolled in sulfur flour; for two other pots, the seed tubers were treated with corrosive sublimate; the remaining three pots were planted with untreated tubers. The new crop showed almost no scab for the corrosive sublimate treatment, while in the sulfur-treated pots there appeared nearly as much scab as in the checks. The other experiment was performed in the field. Five plats were planted with tubers treated with corrosive sublimate; three plats received an application of sulfur flour at the rate of about 150 pounds, and two other plats at the rate of 180 pounds, per acre. After every treated plat there was left an untreated plat as check. The result seems to show that the sulfur treatments did not reduce scab and somewhat increased the yield, although less than the treatment with corrosive sublimate.

In the experiments of Wheeler and Tucker (1896), large iron cans, eighteen inches in diameter and twenty-six inches in depth, were used. Each can received the same amount of the same fertilizers with the exception of lime, which was introduced in different forms for each series of three, with two cans for each kind of lime. One can of each of these series — eight all told — received an application of sulfur at the rate of 600 pounds per acre, the sulfur being thoroughly mixed with the upper 7 to 8 inches of soil. The seed tubers for all cans, before planting, were treated with standard corrosive sublimate solution. The result obtained was as follows:

1. Unlimed cans and those treated with calcium chlorid, with and without sulfur, produced tubers entirely free from scab.

2. Where air-slaked lime was employed, the sulfur treatment showed decrease of scabbed tubers from 100 per cent to 62.5 per cent, and of badly scabbed tubers from 97.2 per cent to 43.8 per cent.

3. Where calcium carbonate and wood ashes were employed, the sulfur treatment reduced the amount of badly scabbed tubers from 100 per cent only to 88.9 and 88.2 per cent, respectively.

4. In the remaining cases—that is, where calcium sulfate, oxalate, and acetate were employed—the sulfur treatment did not reduce the scab at all.

The conclusion of the authors is that the sulfur treatment, “though checking the scab somewhat, was practically useless.”¹

The above experiment was continued the next season by Wheeler and Adams (1898). In experiment A eighteen cans were employed. Each can received, before the experiment began, the same amount of barnyard manure and an application of air-slaked lime at the rate of $2\frac{1}{2}$ tons per acre. The cans were then arranged in groups of three, each group being treated with some substance such as calcium carbonate, sodium chlorid, and others. One group was left untreated. One can from each group of three was planted with untreated seed tubers, another with seed tubers treated in the standard way with corrosive sublimate solution, and the third with tubers rolled in sulfur. The quantity of sulfur used was at the rate of 300 pounds per acre. The sulfur remaining after rolling the seed tubers was dusted over the tubers before they were covered. The reported results of this experiment are as follows:

	Percentage of scabbed tubers	Percentage of badly scabbed tubers
Average without treatment.....	97	71
Average with sulfur treatment.....	93	63
Average with corrosive-sublimate treatment.....	100	69

As may be seen from the above data, the decrease in scabby potatoes due to the sulfur treatment is 4 per cent and the decrease in badly scabbed potatoes is 8 per cent.

In experiment B the same cans were used that were employed in the experiment of the previous season. The general scheme of this experiment was also the same as that of the former experiment, but this time the cans that were sulfured at the rate of 600 pounds per acre during the previous season received an additional application of sulfur at the rate of 300 pounds per acre, the method of application being the same as in experiment A. The result obtained was as follows:

¹ The largest number of tubers secured in any can was twenty, and in some cases there were only two.

Cans treated with calcium sulfate, those treated with calcium chlorid, and those untreated with calcium in any form, produced tubers entirely without scab, whether or not sulfur was applied. Summing up the results obtained with all other treatments, the data on the scab are as follows:

	Percentage of scabbed tubers	Percentage of badly scabbed tubers
Average without treatment.....	91	85
Average with sulfur treatment.....	82	54

The authors concluded that "the indications are that the sulfur treatment of contaminated soils may decidedly reduce the percentage of scab if enough sulfur is employed and the moisture and other soil conditions are such that it is able to exert its maximum effect."

Wheeler, Hartwell, and Moore (1899) conducted some experiments for the purpose of ascertaining the after effect of application of sulfur on the crop following. For this purpose oats and millet were grown in galvanized pots, filled with the same soil as was used in experiment B of the previous year. The conclusion was that although a large quantity of sulfur decreases the scab, it is very injurious to cereals following unless a considerable quantity of lime is introduced into the soil.

Bernhard (1910) reports that during the year 1909 six field experiments were made. He states that in all these experiments the plats treated with sulfur differed from those untreated by a smaller percentage of scabbed potato tubers, and, although in no case did sulfur treatment entirely prevent scab, nevertheless the extent of the disease on sulfured plats was only half of that on untreated plats.

Some experiments were also performed for testing the fertilizing value of sulfur alone and in combination with some common fertilizers. In this connection two experiments are reported, the results of which are fairly uniform and show that the treatment of the soil with flowers of sulfur at the rate of 100 kilograms per one fourth hectare—that is, about 357 pounds per acre—whether alone or in combination with the same amount of 40-per-cent potash, considerably increased the yield on unfertilized as well as on fertilized land; the increase being especially great when sulfur was applied to the plats treated with nitrate of soda 66.66 per cent. The lowest increase was for sulfur on land with superphosphate and double application of potash 6.66 per cent.

From his experiments, Bernhard concludes that the sulfur evidently works in the soil as a disinfecting agent, improves the physical properties of the soil, and appears to play a much greater rôle in nourishment of plants than has formerly been ascribed to it.

Bernhard (1911a) reports on another series of field experiments which in general were of the same type as those of the previous year. The five plats treated with sulfur invariably showed a considerable increase of yield and decrease in scab as compared with those untreated. This holds true whether or not the land was fertilized. The author claims also that the leaf-roll disease of potatoes was less prominent on sulfured plats than on others.

Bernhard (1911b) performed another series of experiments with wooden boxes 40 centimeters square sunk in the earth. In most cases a great reduction of scab was obtained by the addition of 6 grams of sulfur to the boxes, although in some instances, when scabby seed tubers were used, the amount of scab was as high as 60 per cent. Considerable increase in yield due to the use of sulfur was obtained in this experiment. The author thinks that the action of sulfur may be due to its oxidation into sulfur dioxide and finally into sulfuric acid.

From the data on the after effect of sulfur treatment on the potato crop during 1900, Halsted (1901) found "that the untreated belts show a larger number and greater weight of tubers than the other areas, but the value of the larger crop is much less than where the sulfur had been added."

Von Feilitzen (1913), in his experiments in 1911 and 1912 with sulfur treatment of potatoes, found that in case of one variety the results were decidedly beneficial, while in most of the others the advantage was either small or negative.

Pethybridge (1912) tested the effect of different substances, including flowers of sulfur, when applied to the soil at the rate of $3\frac{1}{4}$ and $6\frac{1}{2}$ hundredweight per acre for control of the powdery scab disease (*Spongospora subterranea*). The following year he (1913) again tried sulfur applications to the soil at the rate of $6\frac{1}{2}$ hundredweight per acre. In conclusion of the latter experiment he says (1913:460) that the best treatment was that with "sulphur, where not only was the amount of disease [scab] reduced to less than one half of that in the untreated plots, but the total yield was higher than in any other case. This result confirms previous experiments carried out at Clifden, which have always shown that sulphur added to the soil increases the yield of potatoes and diminishes the attack of scab."

In all three experiments of Pethybridge no duplication of the treatment was made in any way; the checks, one or two plats, being left in only one part of the experimental field. Each plat was one square perch, or 272.25 square feet, in area.

From all the work done with treatment of seed tubers and potato soil, the following conclusions can be drawn:

1. Seed-tuber treatment with corrosive sublimate solution, liquid formaldehyde, and gas formaldehyde proved to be equally satisfactory

whenever the soil was not previously contaminated. Rolling the seed tubers in sulfur often proved to be of little or no service at all.

2. When the soil was contaminated, any of the above seed treatments proved to be of little or no use.

3. None of the substances tried as soil fungicides (kainit, corrosive sublimate, bordeaux, cuprum, and the like), except sulfur, proved to be effective for checking scab.

4. Sulfur (flour and flowers commonly used), whenever applied in sufficient quantity (720 to 900 pounds per acre), reduced scab to a more or less considerable extent; but under certain conditions during the year of application or the following season, it caused a decided decrease in yield. Smaller amounts (300 to 600 pounds per acre) apparently were effective only under certain favorable conditions of soil and weather.

5. From the data existing in the literature on the subject, it seems that the reaction of the soil greatly influences the development of scab, the acidity acting as a checking factor in proportion to its degree.

6. It is also very manifest that fertilizers increasing alkalinity of the soil, such as lime, greatly favor scab development; while acid phosphate, sulfate of ammonia, and the like, at least do not increase scab injuries.

Experimental work at this station

Principles of field experiments

According to Mercer and Hall (1911), "an error is always attached to the result no matter how seemingly uniform is the land and careful the management of the experiment." Moreover, the error may be so great as to render an entire experiment worthless. The latter case is more common than is usually suspected.

The environment and the individuality of every plant are of extreme importance not only in the resultant yield but also in the freedom of the plants from diseases. No individual plant is exactly like another, and no environmental conditions of any plant can be exactly like those of its neighbors. The former and the latter always vary, and often the variation is sufficient to mask the effect of a special treatment that is tested by an experiment. This is as true in the field experimentation of a plant pathologist as it is in the case of a plant-breeder or a soil technologist, unless it can be shown that susceptibility of plants to diseases, and the extent of the injuries caused by the latter, do not vary with plants and environment.

It is improbable that the experimental error due to the two factors above indicated can ever be entirely eliminated, and indeed an entire elimination of it is not important. What is important and what can be done is to diminish the error to a sufficiently low and known degree. Then

it will not interfere with practical conclusions and with a proper interpretation of the experimental results.

In any experiment the aim is to find the effect of the tested treatment, the actual effect for any treatment being evidently equal to the result of the treatment minus the result of no treatment of the same object. Since it is impossible to have the same object treated and untreated simultaneously, the only way to solve the above question is to find a substitute for one of its members. The substitute for the untreated object is known as the check, and it is evident that the more the check is like the treated object minus treatment, the nearer we are to the truth. Hence proper selection of the check is the important point in any experiment. For any field experiment this check must be selected with regard to the soil as well as with regard to the plants.

In respect to the soil checks, Lyon (1912) states that they can be employed with advantage only when they are represented by every other, or at least every third, plat. The checks as they have been commonly used—a few plats or a strip of land left untreated—represent conditions of soil far from the same as those on the treated plats, and therefore mean very little or nothing at all. But even when every other plat or every third plat is left as a check, the check may often differ greatly in soil from the treated plat because of a sudden change in soil. Therefore duplication of the same treatment is absolutely indispensable. Lyon states that the error diminishes by increasing the number of similarly treated plats four or five times, but that there is not much gain in accuracy by a still greater repetition.

In regard to variability in the plant, it has been found that although individual plants do vary considerably, they nevertheless are, on an average, constant enough when a large number of them are considered. Lyon (1912) says that at least one hundred plants must be used in every case. This number apparently is given for cereals; other plants would perhaps differ considerably in this respect.

As the number of plants that could normally be grown on a plat is limited by its size, and as the probable variation in soil is evidently greater when plats are smaller, the size of the plats must also be considered in connection with experimental error. It has been generally accepted that, the larger the plats, the smaller is the expected experimental error. But, as has been shown, this is true only to a certain extent. Thus Mercer and Hall (1911), in their work with mangels and wheat, found that there is no special advantage in using plats larger than one fiftieth acre in size, while Wood and Stratton (1910) found that plats of one eightieth acre in size gave just as small probable error as did the larger plats up to one fourth of an acre in size. Obviously the size of the plat depends

to a considerable extent on the soil conditions, the plant, and the nature of the treatment with which we are dealing.

Thus in a field experiment the following points must be taken as basis for layout of the field:

1. Checks to be left on every other, or at least every third, plat.
2. The same treatment to be repeated four to five times.
3. Each plat to contain at least one hundred plants.
4. The size of the plats to be not less than one eightieth of an acre.

Of course other precautions must be observed, such as to work on as uniform land as possible; to use plants of a pure line; to give the same cultivation and care; and the like.

After observing all means of diminishing the error of field experimentations, there will still be left many other factors that also affect the result and that cannot be controlled and calculated. The error due to these factors can be considered as a casual one, and as such can be determined by calculation of the so-called probable error²; this is a measure of the reliability of the experimental results, and means that the odds are equal that the true result lies somewhere within the actually obtained data $\pm$ probable error.

It is assumed by Wood and Stratton (1910) that desirable precision is that of at least 3.8 times the probable error, corresponding to odds of thirty to one that the result obtained is due to the treatment and not to a chance variation.

Plan for and management of the field experiments

In laying out field experiments and in representing the data obtained from these experiments, the general principles enumerated above were observed in so far as it was practicable under the conditions of the work. In the plan of these experimental fields especial attention was paid to the checks and to repetition of treatments. The treatments that were of primary importance were repeated four and five times, while those treatments that were, from the point of view of the main problem, of secondary importance were repeated at least twice. In one experimental field where sulfur alone was tested, the same treatment was repeated six times. Checks were left on either every third plat or every other plat. The size of plats varied from three eightieths to one eightieth of an acre.

In the tables in which the data are represented the probable error is given wherever it seems to be of any value.

In all the experiments the potatoes were planted either by hand or with a planter, spacing three feet between the rows and eighteen inches be-

² Probable error as worked out is equal to $\pm 0.6745 \sqrt{\frac{\sum d^2}{n(n-1)}}$

tween the plants in the rows. No attempt was made to select clean tubers for seed, nor were they treated with any kind of antiseptic.

During the season of growth all experimental fields were uniformly kept in a proper state of cultivation and were sprayed with bordeaux mixture plus paris green when necessary, so as to keep the crop free from the early and late blights and the potato beetle.

Frequent observations of the growth of the plants on the experimental fields were made; but in no case were any marked differences between the treated and the untreated plats observed, except in the plats that were treated with commercial fertilizer. Those plats always showed a much better growth of the plants when compared with the plants on all other plats.

With the exception of field No. 3, all fields were planted with potatoes of a variety known as "Blue Sprouts No. 9"; field No. 3 was planted with a red potato of the variety Early Manistee.

At digging time the potatoes were sorted in the field into the following classes: clean, entirely free from scab; scabby, the tubers with one to many scab spots; and culls, so badly scabbed as to be unmarketable.

Experiments of 1911

The first field experiments on the value of sulfur treatment of soil for the prevention of potato scab were made by C. N. Jensen, with the author's assistance, in 1911 at Atlanta, New York, on a field which is here referred to as field No. 1.

Because of the absence of a proper system of checks, and also because there was no true duplication of the same treatments, the results obtained from this field are of small value when considered by themselves. But since in their main features they are confirmed by the later work, it perhaps will be of some interest to give here at least a brief account of the results obtained from this field in 1911. These are as follows:

1. In all cases when 900 pounds of sulfur per acre were applied there were very few scabby and almost no cull tubers; on an average the reduction of the total scab was about twenty per cent (19.5 per cent) when compared with the checks, the latter having on an average 6.7 per cent of cull and 22 per cent of scabby tubers. The same application of sulfur was nearly as effective when a small quantity of lime (500 pounds per acre) was added to the sulfured plat.
2. The application of 300 and 600 pounds of sulfur per acre reduced scab only slightly. The reduction was 10.3 and 11.5 per cent in total scab, respectively, when compared with the checks.
3. There was no indication of any reduction of the yield of the crop by sulfur treatment, even when the larger quantity was employed.

Experiments of 1912

Experimental field No. 1.—Notwithstanding the faulty layout of this field, it seemed that the work could be continued here with some profit for one year more, with the object of determining the after effect of sulfur treatment on the same crop, potatoes.

Accordingly the field was planted to potatoes in the spring of 1912. No new application of sulfur was made on the main part of this field, but a commercial fertilizer with potash and phosphate in equal proportion was applied in four strips so as to fertilize one half of each original plat. The data obtained from this part of the field are summed up in Table 1, in

TABLE 1. SUMMARY OF THE DATA FROM FIELD NO. 1, TREATED WITH SULFUR IN 1911

(The plats were approximately one tenth acre in size in 1911. Half of each plat was fertilized with a commercial fertilizer in 1912 — potash 10, phosphoric acid 10, applied at the rate of 650 pounds per acre)

Plats	Treatment	Yield (pounds per acre)	Percent- age of scabby tubers	Percent- age of culls
<i>1911</i>				
3, 5, 9, 13.....	Checks.....	8,620	32.2	7.7
1, 6, 10, 14.....	Sulfur, 300 pounds per acre...	8,390	12.0	2.0
2, 7, 11, 15.....	Sulfur, 600 pounds per acre...	9,047	11.7	1.4
4, 8, 12, 16.....	Sulfur, 900 pounds per acre...	9,600	8.2	0.0
<i>1912, fertilized part</i>				
3, 5, 9, 13.....	Checks in 1911.....	11,955	50.9	14.3
1, 6, 10, 14.....	Sulfur, 300 pounds per acre in 1911.....	11,685	34.3	9.0
2, 7, 11, 15.....	Sulfur, 600 pounds per acre in 1911.....	10,669	15.3	4.3
4, 8, 12, 16.....	Sulfur, 900 pounds per acre in 1911.....	9,088	2.7	0.7
<i>1912, unfertilized part</i>				
3, 5, 9, 13.....	Checks.....	9,567	16.0	5.0
1, 6, 10, 14.....	Sulfur, 300 pounds per acre in 1911.....	7,623	21.2	3.4
2, 7, 11, 15.....	Sulfur, 600 pounds per acre in 1911.....	8,486	3.6	0.1
4, 8, 12, 16.....	Sulfur, 900 pounds per acre in 1911.....	8,569	3.0	0.35

which is given also a similar summary of the data for the same plats for 1911. The quantity of cull, scabby, and clean tubers was determined by sorting the two middle rows of each plat. The table shows that the amount of scab was considerably reduced by application of sulfur at the

FIG. 105

Part A				Part B			
1	Buffer			1	Buffer		
2	Check			2	Check		
3	Sulfur	450 lbs. per acre		3	Sulfur	550 lbs. per acre	
4	Sulfur	900 " " "		4	Sulfur	900 " " "	
5	Check			5	Check		
6	Lime	350 " " "		6	Lime	400 " " "	
7	{ Lime Sulfur	350 " " " 450 " " "		7	{ Lime Sulfur	400 " " " 450 " " "	
8	Check			8	Check		
9	{ Lime Sulfur	350 " " " 900 " " "		9	{ Lime Sulfur	400 " " " 900 " " "	
10	Commercial fertilizer	1000 " " "		10	Commercial fertilizer	900 " " "	
11	Check			11	Check		
12	{ Commercial fertilizer Sulfur	1000 " " " 450 " " "		12	{ Commercial fertilizer Sulfur	900 " " " 450 " " "	
13	Sulfur	450 " " "		13	{ Commercial fertilizer Sulfur	900 " " " 900 " " "	
14	Check			14	Check		
15	Sulfur	900 " " "		15	Sulfur	450 " " "	
16	{ Lime Sulfur	350 " " " 450 " " "		16	Sulfur	900 " " "	
17	Check			17	Check		
18	{ Lime Sulfur	350 " " " 900 " " "		18	Lime	400 " " "	
19	Sulfur	450 " " "		19	{ Lime Sulfur	400 " " " 450 " " "	
20	Check			20	Check		
21	{ Commercial fertilizer Sulfur	1000 " " " 900 " " "		21	{ Lime Sulfur	400 " " " 900 " " "	
22	Check			22	Commercial fertilizer	900 " " "	

Part A				Part B			
23	Commercial fertilizer 1000	lbs.	per acre	23	Check		
24	{ Commercial fertilizer 1000 " " " Sulfur 450 " " "			24	{ Commercial fertilizer 900 lbs. per acre Sulfur 450 " " "		
25	Check			25	{ Commercial fertilizer 900 " " " Sulfur 900 " " "		
26	Sulfur 450	"	" "	26	Check		
27	Sulfur 900	"	" "	27	Sulfur 900	"	" "
28	Check			28	{ Lime 400 " " " Sulfur 450 " " "		
29	Lime 350	"	" "	29	Check		
30	{ Lime 350 " " " Sulfur 450 " " "			30	{ Lime 400 " " " Sulfur 900 " " "		
31	Check			31	Check		
32	{ Lime 350 " " " Sulfur 900 " " "			32	Sulfur 450	"	" "
33	{ Commercial fertilizer 1000 " " " Sulfur 900 " " "			33	Sulfur 900	"	" "
34	Check			34	Check		
35	Sulfur 450	"	" "	35	{ Commercial fertilizer 900 " " " Sulfur 450 " " "		
36	Sulfur 900	"	" "	36	{ Commercial fertilizer 900 " " " Sulfur 900 " " "		
37	Check			37	Check		
38	Buffer			38	Buffer		

FIG. 105.—Field No. 2. General plan of the experiments of 1912 and 1913. Each plat represents 3 rows of potatoes 3 feet apart and 182½ feet long, making 3/80 acre each. The lines represent the buffer rows that were left between each plat.

Part A was treated in 1912. In 1913 it received a general application of commercial fertilizer only, at the rate of 900 pounds per acre. Part B was treated in 1913. In 1912 it received commercial fertilizer at the rate of 1000 pounds per acre and lime at the rate of 350 pounds per acre.

rate of 600 to 900 pounds per acre. It shows also, at least in the case of the fertilized halves, that the yield was decreased by the previous year's application of sulfur, the decrease being largest where the application was heaviest.

Experimental field No. 2.—For the sake of more definite results than could be obtained from field No. 1, it was deemed necessary to conduct the experiments on a more suitable field. Such a field was found near by, and this is known hereafter as field No. 2. This field was under potatoes in 1911, and during that year it produced a comparatively uniform yield with a uniform and considerable amount of scab. The field is level and the soil is of a gravelly loam type closely related to the Dunkirk series, a soil commonly used in the State for potato culture. The layout of this field and the treatment are shown in Fig. 105. It may be seen that the entire field was divided into two equal parts with a strip of land nine feet in width between them. Each part was subdivided into thirty-eight plats, the size of each plat being $182\frac{1}{2}$ by 12 feet, or very close to one twentieth of an acre.

During the season of 1912 only the east part of the field, designated as part A, was used for testing the value of sulfur treatment of the soil for scab. Part B was not treated with sulfur but was used for the purpose of finding the natural variability of the soil in yield and in scab, and also for getting the soil in condition for a still more uniform and thorough contamination with scab for the experiments of the succeeding year. Part B received a uniform application of commercial fertilizer (potash and phosphate 8-10) at the rate of 1000 pounds per acre plus air-slaked lime at the rate of 350 pounds per acre.

In determining treatments and the quantities in which to apply the substances used, it was intended to limit the work to as few different materials as possible so that these few materials could be tested more thoroughly. At the same time such quantities of sulfur were selected that, on the one hand, the smallest quantity might be expected to give a more or less noticeable decrease in scab, while the largest quantity, so far as could be judged, would not be great enough to cause any serious injury to the crop. A small application of lime, alone and with sulfur, was also tested, in the belief that a combination of lime and sulfur might prove to be more beneficial to the crop than sulfur alone. A heavy application of commercial fertilizer was made because of the fact that a heavy application would result in a more pronounced difference, and therefore would give a more definite idea as to the fertilizing value, if any, of sulfur alone and in combination with the fertilizer. This particular kind of fertilizer was chosen because it is commonly used for potatoes by local farmers.

The field was planted, cultivated, and sprayed in the same way as was field No. 1. The fertilizer, lime, and sulfur were applied with a drill, instead of by hand as was done on field No. 1.

The data on scab control from field No. 2, part A, are presented in Table 2. The data were obtained by sorting all the tubers from the three rows of each plat, the fourth row between the plats being left as a buffer row. The tubers were sorted into clean, scabby, cull, and rough-skin tubers. The last named were tubers with a more or less deeply cracked surface. The injury as a rule was not of such a kind as to reduce the value of the crop in any respect. In a few exceptional cases the cracking of the surface of the tubers was sufficient to be objectionable, at least for table use.



FIG. 106.—*Rough-skin tubers found where excess of sulfur was used in connection with commercial fertilizer*

Such a specimen is shown in Fig. 106. The rough skin was observed exclusively on the plats treated with sulfur, and the greatest amount occurred where sulfur and commercial fertilizer were applied together. No such injury was observed during either the preceding or the succeeding season. This season differed from the others in being comparatively very rainy.

The tubers were also sorted, according to their size, into firsts and seconds; but, since these data did not show anything for any of the treatments, they are omitted from the tables.

In Table 2, parallel with the actual data, are given also the data for the calculated checks, with the difference in percentage between the treated

TABLE 2. DATA FOR 1912 FROM FIELD NO. 2, PART A, TREATED IN 1912. ACTUAL

Treatment (pounds per acre)	Plat	Yield		Clean			
		Pounds per plat	Calcu- lated check per- centage	Pounds per plat	Per- centage	Calcu- lated check per- centage	Differ- ence per- centage
Check.....	2	375.00	.....	202.0	53.87	.....	.....
Sulfur 450.....	3	400.50	106.40	273.5	68.29	56.73	11.56
Sulfur 900.....	4	386.50	102.26	313.0	80.98	59.59	21.39
Check.....	5	379.50	.....	237.0	62.45	.....	.....
Lime 350.....	6	398.00	107.01	229.5	57.66	62.27	-4.61
Lime 350 } Sulfur 450 }	7	382.75	104.93	260.5	68.06	62.09	5.97
Check.....	8	357.00	.....	221.0	61.90	.....	.....
Lime 350 } Sulfur 900 }	9	369.00	103.60	309.0	83.74	64.51	19.23
Commercial fertilizer 1000.....	10	507.00	142.68	200.5	39.55	67.12	-27.57
Check.....	11	354.25	.....	247.0	69.72	.....	.....
Commercial fertilizer 1000 } Sulfur 450 }	12	465.50	122.23	273.5	58.75	65.26	-6.51
Sulfur 450.....	13	405.50	99.67	336.5	82.98	60.79	22.19
Check.....	14	433.25	.....	244.0	56.32	.....	.....
Sulfur 900.....	15	415.00	104.48	341.0	82.17	53.57	28.60
Lime 350 } Sulfur 450 }	16	447.25	123.94	351.0	78.48	50.82	27.66
Check.....	17	324.50	.....	156.0	48.07	.....	.....
Lime 350 } Sulfur 450 }	18	405.50	115.51	337.0	83.11	47.30	35.81
Sulfur 900.....	19	390.00	103.28	288.5	73.97	46.53	27.44
Check.....	20	404.25	.....	185.0	45.76	.....	.....
Commercial fertilizer 1000 } Sulfur 900 }	21	513.25	119.11	379.0	73.84	49.69	24.15
Check.....	22	457.50	.....	245.25	53.61	.....	.....
Commercial fertilizer 1000 } Commercial fertilizer 1000 }	23	595.50	137.07	305.5	51.30	57.03	-5.73
Sulfur 450 } Check.....	24	539.75	131.52	310.5	57.53	60.46	-2.93
Sulfur 450.....	25	386.75	.....	247.0	63.87	.....	.....
Sulfur 450.....	26	386.75	100.59	266.5	68.91	65.83	3.08
Sulfur 900.....	27	398.50	104.24	334.0	83.81	67.78	16.04
Check.....	28	380.00	.....	265.0	69.74	.....	.....
Lime 350.....	29	393.00	107.97	233.0	59.29	70.59	-11.30
Lime 350 } Sulfur 450 }	30	411.00	110.93	336.0	81.75	71.44	10.31
Check.....	31	399.75	.....	289.0	72.29	.....	.....
Lime 350 } Sulfur 900 }	32	368.25	89.26	317.0	86.08	72.09	13.99
Commercial fertilizer 1000 } Sulfur 900 }	33	502.25	118.03	413.0	82.23	71.89	10.34
Check.....	34	438.00	.....	314.0	71.69	.....	.....
Sulfur 450.....	35	469.25	102.66	373.0	79.49	71.41	8.08
Sulfur 900.....	36	449.00	94.28	381.0	84.86	71.12	13.74
Check.....	37	495.50	.....	351.0	70.84	.....	.....

plats and the checks. The effect of the treatments on the scab and the yield is shown in Table 3, in which appears the increase or decrease in scab and yield of the treated plats over the corresponding checks. In this table are given also the averages, with their probable errors, for the same kinds of treatment.

From Table 3, it appears (1) that a noticeable decrease of scab was obtained by 450 pounds of sulfur per acre in all cases, except when sulfur was in combination with commercial fertilizer; (2) that the decrease in scab was twice as great when 900 pounds of sulfur was applied, the scab being reduced by this treatment just as much whether sulfur was applied

YIELD AND AMOUNT OF SCAB FOR THE VARIOUS PLATS AND THE CALCULATED CHECKS

Scabby				Culls				Rough skin			
Pounds per plat	Per-cent-age	Calcu-lated check per-cent-age	Differ-ence per-cent-age	Pounds per plat	Per-cent-age	Calcu-lated check per-cent-age	Differ-ence per-cent-age	Pounds per plat	Per-cent-age	Calcu-lated check per-cent-age	Differ-ence per-cent-age
141.0	37.60	.....	.....	32.0	8.53	.....	.....	.....	.....	.....	.....
108.0	26.97	35.95	—8.98	13.5	3.37	7.32	—3.95	5.5	1.37	.....	1.37
54.0	13.97	34.31	—20.34	1.0	0.26	6.10	—5.84	18.5	4.79	.....	4.79
124.0	32.67	.....	.....	18.5	4.88	.....	.....	.....	.....	.....	.....
141.0	35.43	31.86	3.57	27.5	6.91	5.87	1.04	.....	.....	.....	.....
108.0	28.22	31.05	—2.83	13.5	3.53	6.86	—3.33	0.75	0.19	.....	0.19
108.0	30.25	.....	.....	28.0	7.85	.....	.....	.....	.....	.....	.....
50.0	13.55	29.20	—15.65	5.25	1.42	6.29	—4.87	4.75	1.29	.....	1.29
261.5	51.58	28.15	23.43	45.0	8.87	4.73	4.14	.....	.....	.....	.....
96.0	27.10	.....	.....	11.25	3.18	.....	.....	.....	.....	.....	.....
127.0	27.28	31.53	—4.25	33.5	7.20	3.04	4.16	31.5	6.77	0.17	6.60
63.0	15.54	35.96	—20.42	5.0	1.23	2.91	—1.68	1.0	0.25	0.34	—0.09
175.0	40.39	.....	.....	12.0	2.77	.....	.....	2.25	0.52	.....	.....
67.5	16.26	42.95	—26.69	6.0	1.45	3.08	—1.63	0.5	0.12	0.40	—0.28
90.0	20.12	45.51	—25.39	5.25	1.17	3.39	—2.22	1.0	0.23	0.28	—0.05
156.0	48.07	.....	.....	12.0	3.70	.....	.....	0.5	0.16	.....	.....
63.0	15.54	49.20	—33.66	3.0	0.74	3.40	—2.66	2.5	0.61	0.10	0.52
87.5	22.44	50.33	—27.89	10.0	2.56	3.09	—0.53	4.0	1.03	0.05	0.98
208.0	51.40	.....	.....	11.25	2.78	.....	.....	.....	.....	.....	.....
86.0	16.76	47.80	—31.04	5.25	1.02	2.40	—1.38	43.0	8.38	0.11	8.27
202.0	44.15	.....	.....	9.25	2.02	.....	.....	1.0	0.22	.....	.....
260.0	43.66	40.64	3.02	30.0	5.04	2.14	2.90	.....	.....	0.19	—0.19
194.0	35.94	37.12	—1.18	14.75	2.73	2.27	0.46	20.5	3.80	0.15	3.65
130.0	33.61	.....	.....	9.25	2.39	.....	.....	0.5	0.13	.....	.....
109.0	28.18	31.71	—3.53	3.5	0.91	2.38	—1.47	7.75	2.00	0.08	1.92
34.0	8.53	29.80	—21.27	0.5	0.13	2.38	—2.26	30.0	7.53	0.04	7.49
106.0	27.89	.....	.....	9.0	2.37	.....	.....	.....	.....	.....	.....
146.0	37.15	27.10	10.05	14.0	3.56	2.23	1.33	.....	.....	0.08	—0.08
66.0	16.06	26.31	—10.25	5.5	1.34	2.08	—0.74	3.5	0.85	0.17	0.68
102.0	25.52	.....	.....	7.75	1.94	.....	.....	1.0	0.25	.....	.....
17.0	4.62	25.54	—20.92	3.25	0.88	2.21	—1.33	31.0	8.42	0.16	8.26
44.0	8.76	25.56	—16.80	5.25	1.05	2.48	—1.43	40.0	7.96	0.07	7.89
112.0	25.57	.....	.....	12.0	2.74	.....	.....	.....	.....	.....	.....
80.0	17.05	25.45	—8.40	10.0	2.13	3.14	—1.01	6.25	1.33	.....	1.33
29.0	6.46	25.34	—18.88	4.0	0.89	3.54	—2.65	35.0	7.79	.....	7.79
125.0	25.23	.....	.....	19.5	3.93	.....	.....	.....	.....	.....	.....

alone or in combination with lime or with commercial fertilizer; (3) that there was very little, if any, increase in the yield when sulfur alone was applied; (4) that when sulfur was used in combination with commercial fertilizer, the decrease in yield as compared with commercial fertilizer alone was considerable, and the greater decrease was when the larger quantity of sulfur was applied.

On part B of field No. 2, every ninth row was sorted at the time of digging and every grade was recorded. These data are given in Table 4, which shows that the yield varied considerably, yet without sudden jumps except in row No. 15, the yield of which was much lower than that of any

of the next measured rows. This, as it seems, speaks much in favor of using the two nearest checks instead of the average of all checks as a basis of comparison. The table shows also that this part of the field was heavily and uniformly infected with the scab, the amount of scab also not representing sudden jumps from any one of the measured rows to another.

Summary of the work of 1912.—So far as the above data go, the following can be stated: (1) Scab was considerably reduced by an application of sulfur at the rate of 450 to 900 pounds per acre in all cases except when

TABLE 3. PERCENTAGE OF INCREASE (+) OR OF DECREASE (—) IN THE VARIOUS CLASSES OF POTATOES AND IN YIELD FOR FIELD NO. 2, PART A, AS COMPARED WITH THE CORRESPONDING CHECKS. TREATMENT AND DATA FOR 1912 *

Treatment (pounds per acre)	Plat	Clean (percentage)	Scabby (percentage)	Culls (percentage)	Rough skin (percentage)	Yield (percentage)
Sulfur 450.....	{ 3	+11.56	— 8.98	—3.95	+1.37	+ 6.40
	{ 13	+22.19	—20.42	—1.68	—0.09	— 0.33
	{ 19	+27.44	—27.89	—0.53	+0.98	+ 3.28
	{ 26	+ 3.08	— 3.53	—1.47	+1.47	+ 0.59
	{ 35	+ 8.08	— 8.40	—1.01	+1.33	+ 2.66
Average.....		+14.47±2.96	—13.84±3.02	—1.73±0.40	+1.10±0.23	+ 2.52±0.79
Lime 350 } Sulfur 450 }	{ 7	+ 5.97	— 2.83	—3.33	+0.19	+ 4.93
	{ 16	+27.66	—25.39	—2.22	—0.05	+23.94
	{ 30	+10.31	—10.25	—0.74	+0.68	+10.93
Average.....		+14.65±4.47	—12.82±4.48	—2.10±0.51	+0.27±0.14	+13.27±3.78
Commercial ferti- lizer 1000 } Sulfur 450 }	{ 12	— 6.51	— 4.25	+4.16	+6.60	+22.23
	{ 24	— 2.93	— 1.18	+0.46	+3.64	+31.52
Average.....		— 4.72±1.21	— 2.72±1.04	+2.31±1.25	+5.12±1.00	+26.87±3.13
Sulfur 900.....	{ 4	+21.39	—20.34	—5.84	+4.79	+ 2.26
	{ 15	+28.60	—26.69	—1.63	—0.28	+ 4.48
	{ 27	+16.04	—21.27	—2.26	+7.49	+ 4.24
	{ 36	+13.74	—18.88	—2.65	+7.79	— 5.72
Average.....		+19.94±2.23	—21.79±1.15	—3.10±0.63	+4.95±1.26	+ 1.32±1.62
Lime 350 } Sulfur 900 }	{ 9	+19.23	—15.65	—4.87	+1.29	+ 3.60
	{ 18	+35.81	—33.66	—2.66	+0.52	+15.51
	{ 32	+13.99	—20.92	—1.33	+8.26	—10.74
Average.....		+23.01±4.44	—23.41±3.61	—2.95±0.69	+3.36±1.66	+ 2.79±5.08
Commercial ferti- lizer 1000 } Sulfur 900 }	{ 21	+24.15	—31.04	—1.38	+8.27	+19.11
	{ 33	+10.34	—16.80	—1.43	+7.88	+18.03
Average.....		+17.25±4.66	—23.92±4.80	—1.41±0.02	+8.08±0.13	+18.57±0.36
Lime 350.....	{ 6	— 4.61	+ 3.57	+1.04	0.00	+ 7.01
	{ 29	—11.30	+10.05	+1.33	—0.08	+ 7.97
Average.....		— 7.95±2.26	+ 6.81±2.19	+1.18±0.10	—0.04±0.03	+ 7.49±0.32
Commercial fertilizer 1000.....	{ 10	—27.57	+23.43	+4.14	0.00	+42.68
	{ 23	— 5.73	+ 3.02	+2.90	—0.19	+37.07
Average.....		—16.65±7.37	+13.22±6.88	+3.52±0.42	—0.09±0.06	+39.88±1.89

* All probable errors throughout this work were calculated by formula $\pm 0.6745 \sqrt{\frac{\sum d^2}{n(n-1)}}$

TABLE 4. A CLASSIFICATION OF THE YIELD OF POTATOES FROM FIELD NO. 2, PART B, FOR THE YEAR 1912, SHOWING A GENERAL INFESTATION OF SCAB FOR THE SUCCEEDING YEAR

Row	Yield (pounds per acre)	Seconds (percent- age)	Scabby (percent- age)	Culls (percent- age)
7.....	10,550	6.7	52.5	7.6
16.....	9,600	5.0	58.3	10.0
25.....	11,300	4.4	55.9	14.8
34.....	11,680	3.4	60.9	17.8
43.....	11,120	4.8	78.8	20.8
52.....	15,300	3.0	65.6	14.1
61.....	15,960	3.7	72.3	21.2
70.....	13,550	3.1	73.1	28.9
79.....	13,780	3.6	63.7	15.0
88.....	13,680	3.5	62.4	8.1
97.....	13,320	2.7	63.0	10.2
106.....	12,920	3.1	61.2	7.1
115.....	11,480	3.8	64.7	13.2
124.....	13,420	2.8	56.2	5.9
133.....	11,960	6.9	58.1	14.7
142.....	12,340	4.6	52.4	13.5
151.....	13,840	0.0	47.9	13.8

450 pounds of sulfur was applied together with the commercial fertilizer, in which case practically no decrease of scab was obtained. The greatest and most uniform decrease was obtained when 900 pounds of sulfur was applied. (2) In all cases the yield either was not affected or was very slightly increased with sulfur treatment, except when sulfur was applied together with commercial fertilizer, in which case there was a noticeable decrease as compared with commercial fertilizer alone. (3) Both the scab and the yield were decreased by sulfur treatment of the preceding season (Table 1), the decrease of scab being much greater than that of yield.

Experiments of 1913, field No. 2

The experimental work on this field during the season of 1913 was performed as shown in Fig. 105. It is seen that the work on part B in 1913 was nearly an exact duplication of that on part A in 1912, with very few and unimportant deviations as follows: (1) a somewhat more uniform distribution of the number of plats treated in the same way; (2) lime was applied in quantities of 400 pounds instead of 350 pounds per acre; and (3) commercial fertilizer was applied at the rate of 900 pounds instead of 1000 pounds per acre, and contained some nitrogen 2-8-10. Moreover, this spring the potatoes were planted by hand, with the field marked

TABLE 5. DATA FOR 1913 FROM FIELD NO. 2, PART A, TREATED IN 1912. ACTUAL

Treatment (pounds per acre).	Plat	Yield		Clean			
		Pounds per plat	Calcu- lated check (per- centage)	Pounds per plat	Per- cent- age	Calcu- lated check (per- centage)	Differ- ence (per- centage)
Check.....	2	132.50	.....	60	45.28	.....	.....
Sulfur 450.....	3	124.00	92.40	77	62.10	44.19	17.91
Sulfur 900.....	4	103.00	75.74	72	69.90	43.11	26.79
Check.....	5	138.00	.....	58	42.03	.....	.....
Lime 350.....	6	140.00	102.53	38	27.14	44.25	-17.11
Lime 350 }	7	134.00	99.22	58	43.28	46.47	-3.19
Sulfur 450 }	8	133.50	.....	65	48.69	.....	.....
Check.....	9	115.00	89.78	71	61.74	46.58	15.16
Lime 350 }	10	137.50	111.69	45	32.73	44.48	-11.75
Sulfur 900 }	11	118.00	.....	50	42.37	.....	.....
Commercial fertilizer 1000.....	12	105.00	87.28	58	55.24	43.72	11.52
Sulfur 450.....	13	109.00	88.98	80	73.39	45.06	28.33
Sulfur 450.....	14	125.00	.....	58	46.40	.....	.....
Check.....	15	82.50	65.79	56	67.88	44.64	23.24
Lime 350 }	16	123.00	97.74	64	52.04	42.88	9.16
Sulfur 450 }	17	126.50	.....	52	41.11	.....	.....
Check.....	18	113.50	89.06	78	68.72	41.28	27.44
Lime 350 }	19	121.00	94.17	70	57.85	41.45	16.40
Sulfur 900 }	20	129.75	.....	54	41.62	.....	.....
Check.....	21	111.50	82.01	74	66.37	43.66	22.71
Commercial fertilizer 1000.....	22	142.25	.....	65	45.70	.....	.....
Sulfur 900.....	23	150.00	110.01	40	26.67	47.27	-20.60
Commercial fertilizer 1000.....	24	126.00	96.44	66	52.38	48.84	3.54
Sulfur 450.....	25	125.00	.....	63	50.40	.....	.....
Check.....	26	105.00	81.59	69	65.71	50.27	15.44
Sulfur 450.....	27	113.25	85.50	94	83.00	50.14	32.86
Sulfur 900.....	28	136.00	.....	68	50.00	.....	.....
Check.....	29	141.25	102.95	48	33.98	53.48	-19.50
Lime 350 }	30	144.00	104.35	61	42.36	56.96	-14.60
Lime 350 }	31	139.00	.....	84	60.43	.....	.....
Check.....	32	144.00	98.06	112	77.78	59.57	18.21
Lime 350 }	33	142.50	92.14	110	77.19	58.71	18.48
Sulfur 900 }	34	162.50	.....	94	57.85	.....	.....
Check.....	35	164.25	107.78	114	69.41	67.35	2.06
Sulfur 450.....	36	169.75	119.41	136	80.12	76.85	3.27
Sulfur 900.....	37	132.00		114	86.36		
Check.....							

POTATO SCAB AND SULFUR DISINFECTION

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YIELD AND AMOUNT OF SCAB FOR THE VARIOUS PLATS AND THE CALCULATED CHECKS

Scabby				Culls			
Pounds per plat	Per- centage	Calcu- lated check (per- centage)	Differ- ence (per- centage)	Pounds per plat	Per- centage	Calcu- lated check (per- centage)	Differ- ence (per- centage)
69	52.08			3.5	2.64		
47	37.90	53.56	-15.66			2.25	-2.25
31	30.10	55.04	-24.94			1.85	-1.85
78	56.52			2.0	1.45		
100	71.43	53.41	18.02	2.0	1.43	2.34	-0.91
75	55.97	50.30	5.67	1.0	0.75	3.23	-2.48
63	47.19			5.5	4.12		
44	38.26	50.10	-11.84			3.32	-3.32
91	66.18	53.01	13.17	1.5	1.09	2.51	-1.42
66	55.93			2.0	1.70		
47	44.76	54.88	-10.12			1.40	-1.40
29	26.61	53.84	-27.23			1.10	-1.10
66	52.80			1.0	0.80		
26	31.52	54.17	-22.65	0.5	0.60	1.19	-0.59
58	47.15	55.54	-8.39	1.0	0.81	1.58	-0.77
72	56.92			2.5	1.97		
35	30.84	56.70	-25.86	0.5	0.44	2.02	-1.58
50	41.32	56.48	-15.16	1.0	0.83	2.07	-1.24
73	56.26			2.75	2.12		
37	33.18	54.49	-21.31	0.5	0.45	1.85	-1.40
75	52.72			2.25	1.58		
107	71.33	51.14	20.19	3.0	2.00	1.59	0.41
59	46.83	49.57	-2.74	1.0	0.79	1.59	-0.80
60	48.00			2.0	1.60		
34.5	32.86	47.93	-15.07	1.5	1.43	1.80	-0.37
19	16.78	47.86	-31.08	0.25	0.22	2.00	-1.78
65	47.79			3.0	2.21		
87	61.59	44.81	16.78	6.25	4.43	1.71	2.72
80	55.56	41.83	13.73	3.0	2.08	1.21	0.87
54	38.85			1.0	0.72		
31	21.53	39.23	-17.70	1.0	0.69	1.20	-0.51
32	22.46	39.61	-17.15	0.5	0.35	1.68	-1.33
65	40.00			3.5	2.15		
50	30.44	31.21	-0.77	0.25	0.15	1.44	-1.29
33	19.44	22.43	-2.99	0.75	0.44	0.72	-0.28
18	13.64						

TABLE 6. DATA FOR 1913 FROM FIELD NO. 2, PART A, TREATED IN 1912, SHOWING PERCENTAGE OF INCREASE (+) OR OF DECREASE (—) IN THE VARIOUS CLASSES OF POTATOES AND IN YIELD AS COMPARED WITH THE CORRESPONDING CHECKS

Treatment (pounds per acre)	Plat	Clean (percentage)	Scabby (percentage)	Culls (percentage)	Yield (percentage)
Sulfur 450.....	{ 3	+17.91	—15.66	—2.25	—7.60
	{ 13	+28.33	—27.23	—1.10	—11.02
	{ 19	+16.40	—15.16	—1.24	—5.83
	{ 26	+15.44	—15.07	—0.37	—18.41
	{ 35	+2.06	—0.77	—1.29	+7.78
Average.....		+16.03±2.83	—14.78±2.83	—1.25±0.20	—7.02±2.89
Lime 350 } Sulfur 450 }	{ 7 16 30	—3.19 +9.16 —14.60	+5.67 —8.39 +13.73	—2.48 —0.77 +0.87	—0.78 —2.26 +4.35
Average.....		—2.88±4.63	+3.67±4.36	—0.79±0.65	+0.44±1.35
Commercial fertilizer 1000 } Sulfur 450 }	{ 12 24	+11.52 +3.54	—10.12 —2.74	—1.40 —0.80	—12.72 —3.56
Average.....		+7.53±2.69	—6.43±2.49	—1.10±0.20	—8.14±3.99
Sulfur 900.....	{ 4	+26.79	—24.94	—1.85	—24.26
	{ 15	+23.24	—22.65	—0.59	—34.21
	{ 27	+32.86	—31.08	—1.78	—14.50
	{ 36	+3.27	—2.99	—0.28	+19.41
Average.....		+21.54±4.32	—20.42±4.09	—1.12±0.27	—13.39±7.86
Lime 350 } Sulfur 900 }	{ 9 18 32	+15.16 +27.44 +18.21	—11.84 —25.86 —17.70	—3.32 —1.58 —0.51	—10.22 —10.94 —1.94
Average.....		+20.27±2.49	—18.47±2.74	—1.80±0.55	—7.70±1.95
Commercial fertilizer 1000 } Sulfur 900 }	{ 21 33	+22.71 +18.48	—21.31 —17.15	—1.40 —1.33	—17.99 —7.86
Average.....		+20.60±1.43	—19.23±1.41	—1.37±0.02	—12.93±3.42
Lime 350.....	{ 6	—17.11	+18.02	—0.91	+2.53
	{ 29	—19.50	+16.78	+2.72	+2.95
Average.....		—18.31±0.80	+17.40±0.42	+0.91±1.23	+2.74±0.14
Commercial fertilizer 1000.....	{ 10	—11.75	+13.16	—1.41	+11.69
	{ 23	—20.60	+20.19	+0.41	+10.01
Average.....		—16.18±2.99	+16.68±2.37	—0.50±0.61	+10.85±0.57

both ways; so that there was exactly the same number of hills per plat, and at the same time seed pieces of a much more uniform kind could be used than is practicable when a planter is employed.

The field was sprayed, with 4-4-50 bordeaux mixture, only three times, because after the end of July the weather was extremely dry and the plants began to die.

At the time of digging, only two rows of each plat were sorted and weighed separately. The reason for doing this instead of taking three rows, as was done before, was that in digging the potatoes with hooks in the fall of 1912 the surface soil was removed from one plat to the other far enough to warrant discarding another row between the plats. Also, in

order to make the field work uniform only two rows of each plat were sorted on part B, the actual plats still remaining large enough in size (one fortieth of an acre). The treatments of the soil were made exactly in the same manner as during the previous season. The field was also sprayed and cared for about in the same way as before.

The data obtained are given for part A in Table 5 and for part B in Table 7. No rough-skin tubers were observed during this season. The data were then arranged and calculation was made in exactly the same manner as in 1912 for the same field. In Tables 6 and 8 the data are arranged in groups of similar treatment, and show the percentage of increase or decrease in yield and in scab as compared with the corresponding checks.

The after effect of sulfur treatment on the second year's crop of potatoes is shown in Table 6. This effect seems to be as follows: (1) Scab is noticeably reduced with 450 pounds of sulfur per acre only when sulfur was applied alone; when it was applied together with commercial fertilizer, the reduction is slight; and there is no reduction (nor increase) of scab when this quantity of sulfur was applied in combination with lime. (2) Sulfur treatment at the rate of 900 pounds per acre shows a uniform and considerable decrease of scab in all cases. (3) The yield is noticeably decreased by the previous year's sulfur treatment in all cases except when 450 pounds of sulfur was applied together with lime. Even when 900 pounds of sulfur was used in combination with lime, the resulting decrease of yield from the treatment is less than in all other cases.

The data in Table 8 appear somewhat contradictory; but in general practically the same results were obtained as in 1912 from part A of the same field (Table 3), namely: (1) Scab was noticeably decreased by all applications of sulfur, except when 450 pounds per acre was combined with lime, in which case the reduction was not very conspicuous; the greatest and most uniform reduction in scab was effected by the use of 900 pounds of sulfur per acre. (2) The yield was not affected by sulfur alone, was only slightly increased by 450 pounds of sulfur with lime, as compared with lime alone, and was somewhat decreased by sulfur and commercial fertilizer as compared with commercial fertilizer alone.

Summary of the work of 1912 and 1913 on field No. 2

The data obtained from the work of 1912 and 1913 on field No. 2 are summarized and arranged in groups of similar treatment in Table 9, which shows average and total average percentage of increase or decrease in the total scab (scabby tubers plus culls) and in the yield for these two seasons on both parts of the field.

TABLE 7. DATA FOR 1913 FROM FIELD NO. 2, PART B, TREATED IN 1913. ACTUAL

Treatment (pounds per acre)	Plat	Yield		Clean			
		Pounds per plat	Calcu- lated check (per- centage)	Pounds per plat	Per- cent- age	Calcu- lated check (per- centage)	Differ- ence (per- centage)
Check.....	2	105.00	.....	40	38.10	.....	.....
Sulfur 550.....	3	113.00	108.66	74	65.49	38.15	27.34
Sulfur 900.....	4	100.00	97.09	80	80.00	38.20	41.80
Check.....	5	102.00	.....	39	38.24	.....	.....
Lime 400.....	6	113.50	108.61	28	24.67	34.61	—9.94
Lime 400 }	7	114.50	124.27	53	46.29	30.97	15.32
Sulfur 450 }							
Check.....	8	109.75	.....	30	27.33	.....	.....
Lime 400 }	9	115.25	100.92	80	69.41	23.65	45.76
Sulfur 900 }							
Commercial fertilizer 900..	10	159.50	134.56	24	15.05	19.97	—4.92
Check.....	11	122.75	.....	20	16.29	.....	.....
Commercial fertilizer 900 }	12	143.25	122.91	50	34.90	15.34	19.56
Sulfur 450 }							
Commercial fertilizer 900 }	13	137.25	124.32	80	58.29	14.39	43.90
Sulfur 900 }							
Check.....	14	104.25	.....	14	13.43	.....	.....
Sulfur 450.....	15	115.75	101.05	38	32.83	16.10	16.73
Sulfur 900.....	16	136.25	109.00	75	55.05	18.77	36.28
Check.....	17	135.25	.....	29	21.44	.....	.....
Lime 400.....	18	122.00	90.33	18	14.75	23.48	—8.73
Lime 400 }	19	128.50	95.54	38	29.57	25.52	4.05
Sulfur 450 }							
Check.....	20	134.25	.....	37	27.56	.....	.....
Lime 400 }	21	133.00	98.78	80	60.15	26.73	33.42
Sulfur 900 }							
Commercial fertilizer 900..	22	162.00	120.00	38	23.46	25.91	—2.45
Check.....	23	135.50	.....	34	25.09	.....	.....
Commercial fertilizer 900 }	24	130.00	104.96	66	50.77	30.29	20.48
Sulfur 450 }							
Commercial fertilizer 900 }	25	127.00	113.08	88	69.29	35.49	33.80
Sulfur 900 }							
Check.....	26	100.75	.....	41	40.69	.....	.....
Sulfur 900.....	27	108.50	104.03	74	68.20	39.41	28.79
Lime 400 }	28	120.50	111.84	48	39.84	38.13	1.71
Sulfur 450 }							
Check.....	29	111.25	.....	41	36.85	.....	.....
Lime 400 }	30	127.50	110.39	90	70.59	38.22	32.37
Sulfur 900 }							
Check.....	31	121.25	.....	48	39.59	.....	.....
Sulfur 450.....	32	110.00	92.32	55	50.00	40.28	9.72
Sulfur 900.....	33	111.75	95.39	58	51.90	40.97	10.93
Check.....	34	115.25	.....	48	41.65	.....	.....
Commercial fertilizer 900 }	35	132.25	117.76	62	46.88	43.96	2.92
Sulfur 450 }							
Commercial fertilizer 900 }	36	138.50	126.27	80	57.76	46.28	11.48
Sulfur 900 }							
Check.....	37	107.00	.....	52	48.60	.....	.....

YIELD AND AMOUNT OF SCAB FOR THE VARIOUS PLATS AND THE CALCULATED CHECKS

Scabby				Culls			
Pounds per plat	Per- centage	Calcu- lated check (per- centage)	Differ- ence (per- centage)	Pounds per plat	Per- centage	Calcu- lated check (per- centage)	Differ- ence (per- centage)
65	61.90						
39	34.51	61.52	—27.01			0.33	—0.33
20	20.00	61.15	—41.15			0.65	—0.65
62	60.78			1.0	0.98		
80	70.48	63.60	6.88	5.5	4.85	1.79	3.06
60	52.40	66.43	—14.03	1.5	1.31	2.60	—1.29
76	69.25			3.75	3.42		
32	27.77	71.96	—44.19	3.25	2.82	4.39	—1.57
129	80.88	74.67	6.21	6.5	4.07	5.36	—1.29
95	77.39			7.75	6.32		
80	55.85	77.81	—21.96	13.25	9.25	6.85	2.40
54	39.34	78.23	—38.89	3.25	2.37	7.38	—5.01
82	78.66			8.25	7.91		
67	57.88	77.08	—19.20	10.75	9.29	6.82	2.47
59	43.30	75.51	—32.21	2.25	1.65	5.72	—4.07
100	73.94			6.25	4.62		
74	60.66	72.39	—11.73	30.0	24.59	4.13	20.46
86	66.93	70.83	—3.90	4.5	3.50	3.65	—0.15
93	69.27			4.25	3.17		
46	34.59	69.55	—34.96	7.0	5.26	3.72	1.54
112	69.14	69.83	—0.69	12.0	7.40	4.26	3.14
95	70.11			6.5	4.80		
62	47.69	65.93	—18.24	2.0	1.54	3.78	—2.24
39	30.71	61.75	—31.04			2.76	—2.76
58	57.57			1.75	1.74		
34	31.34	57.86	—26.52	0.5	0.46	2.73	—2.27
67	55.60	58.15	—2.55	5.5	4.56	3.72	0.84
65	58.43			5.25	4.72		
35	27.45	57.67	—30.22	2.5	1.96	4.11	—2.15
69	56.91			4.25	3.50		
51	46.36	55.87	—9.51	4.0	3.64	3.85	—0.21
51	45.64	54.83	—9.19	2.75	2.46	4.20	—1.74
62	53.80			5.25	4.55		
66	49.91	53.00	—3.09	4.25	3.21	3.04	0.17
58	41.88	52.20	—10.32	0.5	0.36	1.52	—1.16
55	51.40						

TABLE 8. DATA FOR 1913 FROM FIELD NO. 2, PART B, TREATED IN 1913, SHOWING PERCENTAGE OF INCREASE (+) OR OF DECREASE (—) IN THE VARIOUS CLASSES OF POTATOES AND IN YIELD AS COMPARED WITH THE CORRESPONDING CHECKS

Treatment (pounds per acre)	Plat	Clean (percentage)	Scabby (percentage)	Culls (percentage)	Yield (percentage)
Sulfur 550 }	{ 3	+27.34	—27.01	—0.33	+ 8.66
Sulfur 450 }	{ 15	+16.73	—19.20	+ 2.47	+ 1.05
	{ 32	+ 9.72	— 9.51	— 0.21	— 7.68
Average		+17.93±3.45	—18.57±3.41	+ 0.64±0.61	+ 0.68±3.18
Lime 400 }	{ 7	+15.32	—14.03	— 1.29	+24.27
Sulfur 450 }	{ 19	+ 4.05	— 3.90	— 0.15	— 4.46
	{ 28	+ 1.71	— 2.55	+ 0.84	+11.84
Average		+ 7.03±2.83	— 6.83±2.44	— 0.20±0.42	+10.55±5.61
Commercial fertilizer 900 }	{ 12	+19.56	—21.96	+ 2.40	+22.91
Sulfur 450 }	{ 24	+20.48	—18.24	+ 2.24	+ 4.96
	{ 35	+ 2.92	— 3.09	+ 0.17	+17.76
Average		+14.32±3.85	—14.43±3.89	+ 0.11±0.90	+15.21±3.60
Sulfur 900	{ 4	+41.80	—41.15	— 0.65	— 2.91
	{ 16	+36.28	—32.21	— 4.07	+ 9.00
	{ 27	+28.79	—26.52	— 2.27	+ 4.03
	{ 33	+10.93	— 9.19	— 1.74	— 4.61
Average		+29.45±4.53	—27.27±4.55	— 2.18±0.48	+ 1.38±2.12
Lime 400 }	{ 9	+45.76	—44.19	— 1.57	+ 0.92
Sulfur 900 }	{ 21	+33.42	—34.96	+ 1.54	+ 1.22
	{ 30	+32.37	—30.22	— 2.15	+10.39
Average		+37.18±2.90	—36.45±2.77	— 0.73±0.78	+ 3.36±2.41
Commercial fertilizer 900 }	{ 13	+43.90	—38.89	— 5.01	+24.32
Sulfur 900 }	{ 25	+33.80	—31.04	— 2.76	+13.08
	{ 36	+11.48	—10.32	— 1.16	+26.27
Average		+29.73±6.39	—26.75±5.75	— 2.98±0.76	+21.22±2.77
Lime 400	{ 6	— 9.94	+ 6.88	+ 3.06	+ 8.61
	{ 18	— 8.73	—11.73	+20.46	+ 9.67
Average		— 9.34±0.41	— 2.42±6.28	+11.76±5.87	— 0.53±6.16
Commercial fertilizer 900	{ 10	— 4.92	+ 6.21	— 1.29	+34.56
	{ 22	— 2.45	— 0.69	+ 3.14	+20.00
Average		— 3.68±0.84	+ 2.76±2.33	+ 0.92±1.50	27.28±4.90

On the whole Table 9 indicates: (1) That the most efficient and uniform decrease of scab during the year of the treatment, and also during the season after, was obtained with 900 pounds of sulfur per acre, especially in combination with lime. (2) That during the season of treatment a decrease in yield was noticeable only when sulfur was applied together with commercial fertilizer as compared with commercial fertilizer alone; nor was there any pronounced increase in yield by any other sulfur treatment. (3) That as a rule the effect of sulfur treatment on the crop of the next succeeding season was more or less injurious, except when 450 pounds of sulfur per acre was applied in combination with lime, in which case there was no decrease in yield at all. The decrease in yield was especially

TABLE 9. AVERAGE AND TOTAL AVERAGE PERCENTAGE OF INCREASE (+) AND OF DECREASE (—) IN TOTAL SCAB* AND IN YIELD FOR 1912 AND 1913, FIELD NO. 2†

Treatment (pounds per acre)	Percentage of scab			Percentage of yield		
	Field No. 2, part A		Field No. 2, part B	Field No. 2, part A		Field No. 2, part B
	Treatment and data for 1912	Treatment 1912, data 1913	Treatment and data for 1913	Treatment and data for 1912	Treatment 1912, data 1913	Treatment and data for 1913
Sulfur 450	—15.57±3.05	—16.03±2.83	—17.93±3.45	+2.52±0.79	—7.02±2.89	+0.68±3.18
Lime 350 and 400.....Sulfur 450	—14.92±4.51	+2.88±4.63	—7.03±2.83	+13.27±3.78	+0.44±1.35	+10.55±5.61
Commercial fertilizer 900	—	—	—	+26.87±3.13	—8.14±3.09	+15.21±3.60
and 1000.....Sulfur 450	—0.41±1.63	—7.53±2.69	—14.32±3.85	—	—	—
Average of all plats treated with sulfur 450‡	—10.30±5.50	—6.89±6.06	+13.09±5.89	+14.22±4.97	—4.91±4.44	+8.81±7.39
Sulfur 900	—24.89±1.31	—21.54±4.32	—29.45±4.53	+1.32±1.62	—13.39±7.86	+1.38±2.12
Lime 350 and 400.....Sulfur 900	—26.36±3.68	—20.27±2.49	—37.18±2.90	+2.79±5.08	—7.70±1.95	+3.36±2.41
Commercial fertilizer 900	—	—	—	+18.57±0.36	—12.93±3.42	+21.22±2.77
and 1000.....Sulfur 900	—25.33±4.80	—20.60±1.43	—29.73±6.39	—	—	—
Average of all plats treated with sulfur 900	—25.53±6.19	—20.80±5.17	—32.12±8.35	+7.56±5.34	—11.34±8.79	+8.65±4.24
Checks	0.00	0.00	0.00	0.00	0.00	0.00
Lime 350 and 400.....	+7.99±2.19	+18.31±0.80	+9.34±0.41	+7.49±0.32	+2.74±0.14	—0.53±6.16
Commercial fertilizer 900 and 1000.....	+16.74±6.89	+16.18±2.99	+3.68±0.84	+39.88±1.89	+10.85±0.57	+27.28±4.90
Average of all plats without sulfur and including the checks.....	+8.24±7.23	+11.50±3.10	+4.34±0.93	+15.79±1.92	+4.53±0.59	+8.92±7.87

* Total scab was found by combining scabby and cull tubers. In all cases, except for 1912 when rough-skin tubers were also included, the decrease of the total scab and, of course, its probable error, correspond exactly to the increase of clean tubers.

† In this table probable errors for total scab, 1912, and for all the total averages, were calculated from formula $E_a = \sqrt{E_1^2 + E_2^2}$ in which formula E_a stands for the probable error of the averages, E_1 and E_2 for the probable error of the first and the second data, respectively.

‡ One plat in field No. 2, part B, received sulfur at the rate of 550 pounds per acre in 1913.

prominent when 900 pounds of sulfur was applied either alone or with commercial fertilizer, and the least prominent decrease (-7.70 ± 1.95) in yield was when the application of 900 pounds of sulfur was made together with lime.

FERTILIZING VALUE OF SULFUR

Present information in regard to the fertilizing value of sulfur

In the course of several years there have appeared a number of articles dealing with the use of sulfur as a fertilizer. It will not be necessary here to go into a detailed consideration of the literature existing on this subject, but only to refer briefly to some of the work that represents the main findings in this regard.

The work of Marès (1869), Pollacci (1874), and others indicates that sulfur, when introduced into soil and in presence of sufficient moisture, heat, and oxygen, oxidizes finally to sulfuric acid and, according to Demolon (1912), various sulfates are eventually formed.

The fertilizing effect of sulfur observed in many instances is explained differently by different authors. The work of Hart and Peterson (1911) seems to indicate that, contrary to the generally accepted views, the requirement for sulfur in many plants is comparatively very high; hence in the case of certain plants and soils, sulfur has a direct fertilizing value.

According to others the action of sulfur is indirect. Thus Boullanger and Dugardin (1912) believe that sulfur acts beneficially in the soil through the stimulation of activities of certain micro-organisms, whereby the amount of available ammonium is increased; while Demolon (1913) thinks that it acts also through the sulfuric acid produced by sulfur on its oxidation, the acid liberating other nutritive substances of the soil, especially salts of potassium. Although some of the work reported has not been well checked, it appears that sulfur acts in certain cases as a valuable fertilizer.

From the existing literature on the subject, there are indications that for increase in yield the smaller quantities of sulfur are just as good as, or even better than, the larger quantities. Sulfur seems to be injurious to the plants when it is applied to soils poor in carbohydrates (Demolon, 1913). The after effect of sulfur, at least on certain cereals, is, as shown by Wheeler, Hartwell, and Moore (1899), evidently injurious when large quantities are applied. Halsted (1898) reports that once in his experiment with sulfur a heavy application (720 pounds per acre) reduced the yield of potatoes to nearly one half of the normal.

Experimental work

Our experiments, reported in the foregoing pages, show that, for the soils experimented with, a sulfur application of 300 to 900 pounds per acre in

the first year on the whole slightly increases rather than decreases the yield of potatoes; except when the soil receives at the same time a heavy application of potash and phosphoric acid, in which case the effect of sulfur usually is negative. The effect of an application of sulfur of 450 to 900 pounds per acre on a second year's crop of potatoes seems to be, as a rule, that of more or less reducing the yield, except when the application of sulfur is combined with lime; the use of lime with 450 pounds of sulfur seems to prevent any decrease, and with 900 pounds of sulfur the decrease is considerably diminished (-7.7 per cent ± 1.95 per cent).

In order to ascertain, at least in a preliminary way, whether sulfur has indeed any fertilizing value for potatoes, and if so in what quantities, an experiment was conducted in the season of 1913 on the farm of Charles Wolcott, Atlanta, New York. The soil of the field is Volusia loam, one of the soils extensively used in this State for potatoes. The whole field is of a fairly uniform nature, but slightly sloping northward. It comprises only a small area in the whole potato field, and there was no opportunity to arrange the plats otherwise than along the slope in conformity with other rows in the field. At the time of beginning this experiment there seemed to be no special objection to such an arrangement; but, as the data show, the yield was in places extremely variable, perhaps because of slightly greater or less seepage of the subsoil water—which might have an unusually important effect on the crop during that exceptionally dry season.

The general trend of the data obtained from this experiment seems to indicate definitely: (1) that the application of about 100 pounds of sulfur per acre somewhat increases the yield; (2) that applications of 50, 200, and 300 pounds of sulfur per acre have more or less neutral effect on the yield; and (3) that the yield was materially decreased when sulfur was applied at the rate of 500, 700, and 900 pounds per acre.

The results obtained are somewhat in accord with some of the work briefly mentioned above on the fertilizing value of sulfur, and therefore might be accepted as final; but since on the whole the data are too irregular to allow drawing any final conclusions, they are not given here.

It is evident that a series of careful and thorough experiments along these lines is much needed; and, according to Thatcher (1912), some work laid out on an exceptionally broad plan has been carried on by the United States Department of Agriculture, but no results have as yet been published.

GENERAL SUMMARY OF WORK DONE

From our work on sulfur treatment of the soil against potato scab it is evident that by application of sulfur in a sufficient quantity—450 to 900 pounds per acre—if the application is made broadcast and the sulfur is

thoroughly mixed with about two inches of the surface soil just before potatoes are planted, the amount of scab can be considerably reduced, especially by the heavier application of sulfur. This is true at least in case of the soils of the Dunkirk series commonly used for potato culture. In no case, however, even by the heaviest of the tested applications of sulfur, was the scab entirely eliminated.

When lime was applied at the rate of 350 to 400 pounds per acre, together with 450 pounds of sulfur per acre, the fungicidal power of the latter was in some cases reduced to nearly nil; while the same quantity of lime with 900 pounds of sulfur did not reduce the fungicidal value of sulfur at all, and at the same time diminished the injurious after effect of sulfur treatment on the crop.

As a rule, the effect of sulfur treatment on the same crop in the next succeeding season is that of reducing yield and scab, the scab being reduced more than the yield.

Sulfur added to commercial fertilizer reduces the value of the fertilizer more or less noticeably.

A small quantity of sulfur—about 100 pounds per acre—may prove to be of fertilizing value for potatoes, at least on certain soils, for which at the same time sulfur in quantities over 300 pounds per acre appears to be more or less injurious to the same crop.

As a general remark in regard to the actual effect of sulfur treatment on scab, it is proper to call attention here to the fact that the mere percentage of increase or decrease, as the case may be, of the scabby tubers, as shown in our data, does not give a fair idea of the actual effect of the treatment on the extent of the scab injury. A tuber with only one scab spot and one with several would be in the same lot of scabby tubers. And, as a rule, the greater the number of scabby tubers, the greater is the extent of the injury; so that when a treatment reduces the total amount of scab—for example, from 40 to 20 per cent—the actual reduction usually is much greater than 20 per cent because the scab injury in the latter case is not so intense as in the former.

Grading of the tubers according to the extent of the injury into several classes would, of course, help much to record this difference; but such grading of the tubers is not practicable under the conditions of an extensive field experiment.

The effect of sulfur treatment on the percentage of culls—that is, the tubers very badly scabbed—has not been discussed in this paper at all because the percentage of culls was small and therefore did not present good material for comparative study of the effect of the various treatments. From the tables given in this work, however, it is evident that the decrease in the number of culls was at least as great as that in the scabby potatoes.

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